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The purpose of this study was to determine the efficacy of using linear programming as a tool to support decisions involving surgical case mix at Naval Medical Center Portsmouth, Virginia. This study used estimates of CHAMPUS prospective payments and direct care (facility) costs to differentiate surgical discharges arrayed by Diagnosis Related Groups (DRGs). Results of this study indicate that linear programming is an effective adjunct to data driven analysis, particularly regarding decisions seeking optimization of existing resources.

This study includes both a template for utilizing linear programming with surgical DRGs and an interpretation of the linear programming model developed using Naval Medical Center Portsmouth's top fifty surgical DRGs, constrained by surgical patient bed days and estimates of operating room capacity.

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U. S. ARMY-BAYLOR UNIVERSITY
GRADUATE PROGRAM IN HEALTH CARE ADMINISTRATION

USING LINEAR PROGRAMMING TO MANAGE SURGICAL DIAGNOSIS RELATED GROUPS (DRGs) AT NAVAL MEDICAL CENTER, PORTSMOUTH, VIRGINIA

A GRADUATE MANAGEMENT PROJECT
SUBMITTED TO:

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IN PARTIAL FULFILLMENT OF CANDIDACY REQUIREMENTS FOR THE DEGREE OF MASTER OF HEALTH ADMINISTRATION

BY
LIEUTENANT JEFFREY C. TROWBRIDGE, MSC, USNR, CHE

PORTSMOUTH, VIRGINIA

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ABSTRACT

The purpose of this study was to determine the efficacy of using linear programming as a tool to support decisions involving surgical case mix at Naval Medical Center Portsmouth, Virginia. This study used estimates of CHAMPUS prospective payments and direct care (facility) costs to differentiate surgical discharges arrayed by Diagnosis Related Groups (DRGs). Results of the study indicate that linear programming is an effective adjunct to data driven analysis, particularly regarding decisions seeking optimization of existing resources.

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INTRODUCTION

In June 1990, Naval Medical Center, Portsmouth (NMCP) broke ground on the $330 million Acute Care Facility (ACF). The ACF replaces the aging main hospital structure completed in 1960. The one million square foot ACF design supports the more than 400,000 Military Health Services System (MHSS) beneficiaries residing in the Hampton Roads area.

Located in southeastern Virginia, the Hampton Roads area is home to Norfolk Naval Base, the world's largest naval base, and includes the cities of Chesapeake, Norfolk, Portsmouth, Suffolk, Virginia Beach, Hampton and Newport News. The total population in the Hampton Roads area is more than 1.5 million (Guide to Hampton Roads 1996).

Besides serving the needs of all military, family member and retirees in the Hampton Roads area, NMCP serves as a major tertiary care referral center for military hospitals worldwide. The 363-bed facility has an average inpatient census of 244 and, along with affiliated branch clinics, treats about 1.75 million outpatients each year (Naval Medical Center Portsmouth 1995a). NMCP's large size and range of available services contribute to the complexity of managing military health care in the Hampton Roads area. The hospital's complexity manifests itself in strategic decisions ranging from meeting contingency requirements to resource allocation.

Resource allocation is a major issue at most large hospitals, and NMCP is no exception. The Assistant Director for Administration, NMCP, Lieutenant Commander Thomas Schneid, expressed concerns about resource allocation, especially as it relates to surgical production decisions at the hospital. His concern was that surgical service decisions did not consider environmental constraints and optimization of available operating room time. Specifically, he voiced a concern for the systemic effect on NMCP of surgical production decisions in the new ACF (Schneid 1995).

A second factor important to resource allocation involves NMCP's pioneering military managed care endeavors. In 1992, the first major military managed care demonstration project started in the Hampton Roads area. This project included all area Military Treatment Facilities (MTFs): McDonald Army Community Hospital at Fort Eustis, Portsmouth Naval Medical Center, and the 1st Medical Group at Langley Air Force Base. The hospital commanders established a board to coordinate care among military and civilian sources using a more aggressive managed care philosophy (Starr 1993).

This new approach was a direct reaction to the grim reality of decreasing resources. The demonstration project was an early effort to apply the principal tenets of managed care to the MHSS. According to Stephen Backhus of the General Accounting Office, "the military has a captive audience, the military should be able to control all aspects of health care; if it (managed care) can't work in the military, I don't know that it can work anywhere" (Starr 1993).

Extending the idea of managed care to health services management on a regional basis, optimization of existing resources is vital to system efficiency and regional reorgani-

zation requirements. The Office of the Assistant Secretary of Defense stated that the Coordinated Care Program (an earlier incarnation of managed care in the MHSS) requires reorganizing the MHSS into comprehensive health care networks instead of the current dichotomy between MTFs and the Civilian Health and Medical Program of the Uniformed Services (CHAMPUS) (U. S. Department of Defense 1992).

Managers use quantitative analysis techniques to coordinate efficient use of resources. One branch of quantitative analysis is operations research, a management science that offers techniques to ensure exceptional results from fewer resources (Butler 1995). One such operations research tool is linear programming, a management science instrument that solves the problem of maximizing or minimizing a linear objective function subject to specific linear constraints (Hughes and Soliman 1985). Linear programming seems a perfect device to answer questions surrounding optimizing the utilization of existing resources and as a technique for sorting out complex issues, such as surgical production decisions at NMCP. This Graduate Management Project (GMP) explores one method of optimizing utilization of available resources through development of a linear programming model.

In the past, health care management and operations research were often regarded as mutually exclusive professional fields. However, the trend toward quantitative analysis in health care administration continues and is helping to reshape the American health care environment as the evolution towards capitation and cost containment progresses.

In 1978, William L. Dowling, Director of the Graduate Program in Health Services Administration at the University of Washington, published Hospital Production - A Linear Programming Model. This publication contains a comprehensive examination of hospital production using linear programming. Dowling thoroughly summarizes the applications and limitations (conceptual and practical) of modeling such a complex function as hospital production. Dowling concluded that a linear programming model does provide a method of evaluating the effects of different specifications of the objective function on the optimal mix and volume of patients and of determining how far from any given optimum a hospital is operating (Dowling 1978). However, the model's development predated implementation of Diagnosis Related Groups (DRGs) and much of Dowling's work involved determination and application of his own diagnostic categories. Dowling also shows how linear programming models can measure the effects of different patient mixes on the objective function as related to hospital policy; and how linear programming can be used across a number of hospitals vice a single facility.

By 1985, William L. Hughes and Soliman Y. Soliman applied linear programming to determine a hospital's financially optimal case mix (Hughes and Soliman 1985). This practical, comprehensive application serves as the fountainhead of the data and research applied in this GMP. Hughes and Soliman provide a framework for applying Medicare

prospective payment amounts to typical hospital DRGs. In their study, Hughes and Soliman use length of stay, availability of surgical time, Computerized Axial Tomography scan time, Neonatal Intensive Care Unit availability, and labor and delivery hours as constraining resources to develop their linear programming formulation.

In a 1987 case study, Grant and Hendon used linear programming to maximize use of limited hospital advertising dollars. The following year, the Journal of Health Care Marketing featured an article that used linear programming to formulate an objective function that maximized hospital total net revenues using two different decision variables: the price for nursing care and the price for laboratory care (Heshmat 1988). This technique assisted hospital decision makers in the allocation of rate increases among hypothetical hospital charge accounts.

Linear programming also has applications to economic optimization of nurse work schedules (Harmeir 1991) and enhancement of clinical decision making (Hershey 1991). The process can also help determine the financially optimal mix of patients for a solo ophthalmic practice (Frenkel and Minieka 1982).

Cokelez and Peacock use linear programming as part of an integrated, analytical approach to targeting locations of health care facilities. They use subjective and objective factors to develop a unified approach to identify the optimal locations to construct new health care centers. Their linear programming formulations dealt with the trade-offs between transportation costs and the costs associated with location and facility operation (Cokelez and Peacock 1993).

Singh, May and Messick describe the importance of extending system analysis techniques to broader questions of resource utilization, treatment costs, and allocation of manpower (Singh, May and Messick 1978). They submit that the validated techniques of operations research, which have already proven successful in private industry, have specific applications to health care. However, application of operations research techniques to health care systems is relatively new, but their use will undoubtedly spread, for the techniques offer a basis for more scientific and objective decisions (Singh, May and Messick 1978). Singh, May and Messick also describe questions that linear programming techniques can answer.

According to Butler, management science and operations research (MS/OR) can help health care administrators become more efficient in this day of intense competition (Butler 1995). Butler cites linear programming, simulation, multivariate statistical analysis, decision analysis, project evaluation and review technique models and other methods available to aid decision makers. However, Butler cautions that MS/OR techniques must be tempered by the theories underlying their use, including the assumptions underlying studies and issues of verification and validation of data. Butler finishes his review by listing guidelines for users of MS/OR data, including the steps required when building an MS/OR project: problem definition, model construction, testing and implementation (Butler 1995). This GMP includes the first two steps of Butler's recommended methodology.

Lieutenant Thomas Dowty described the need for Navy medicine to possess the ability to make decisions even faster than before and with greater accuracy. Dowty dis-

cussed the advantages of operations research techniques to Navy medicine, and included an example of linear programming used as a decision making tool (Dowty 1995).

Robert Fetter and Jean Freeman describe the development of DRGs and their implications for improving hospital management (Fetter and Freeman 1986). They describe DRGs as a multivariable system for classifying hospital discharges from acute care hospitals into patient groups or types of cases with similar expected patterns of resource consumption (Fetter and Freeman 1986). They conclude that DRGs provide hospital administrators and physicians with a mechanism to define hospital production and allow for analysis for quality and efficiency improvements. The variables used in this GMP are DRGs, precisely because they do allow for quality and efficiency analysis and allow for comparisons between civilian and military hospitals. Additionally, Fetter and Freeman suggest that a matrix-type management structure that recognizes DRGs as defined groups of patients is the optimal method of management control. Hubble sees DRGs as mechanisms forcing hospitals to look closely at actual costs of providing specific services (Hubble 1985). In a similar article, DRGs are used to differentiate product lines to be designed, controlled and budgeted via cost accounting methodologies (Fetter, Freeman and Mullin 1985).

DRGs have also been described as a managerial definition of a product in an institution that many view as a multi-product firm. This definition was used in designing a linear programming model to facilitate short-term case mix management (Hughes and Soliman 1985). Hospitals also use DRGs for product-driven budgeting to differentiate hospital products along DRGs (Solovy 1989). Jones (1994) describes DRGs as the foundation

for clinical assessment, reimbursement analysis, budgeting, and strategic planning. Naidu, Kleimenhagen and Pillari review the level of implementation of DRG-based product line management in a 1993 study. The results of this study demonstrate that product line management is a beneficial management tool for hospitals, especially to the financial outcome of hospitals that implement product line management (Naidu, Kleimenhagen and Pillari 1993).

The purpose of this GMP is to recommend an optimal surgical case mix using linear programming as the decision making tool. A decision making tool based on the allocation of scarce resources among alternative combinations of surgical DRGs. The GMP does not profess to contribute to the science of operations research or expand the frontiers of linear programming methodologies. However, it does examine one part of hospital efficiency and the manner in which the outputs of the surgical departments of NMCP are combined to produce surgical care in the short run (Dowling 1978).

Reliability and validity are important components in any research design. For linear programming models, it is important that all relevant variables and constraints have been considered and correctly inputted into the data set (Butler 1995). However, because a model is being constructed -- even questionable accuracy of estimated capacities is not considered a serious limitation, because these capacities (bed days and surgical capacity) are considered policy variables, rather than absolute parameters (Dowling 1978). Specific model limitations and assumptions are included in sections detailing surgical constraint formulations.

Because the outputs of the surgical department depend on utilization of the operating room, a notoriously high-cost center (Calmes and Shusterich 1992), the GMP focuses on maximizing use of the operating room suites at NMCP. Indeed, the literature contains many references to the strong effect of improved operating room productivity on financial results, despite the complexity and impenetrable circles of influence inherent in operating room functioning (Clemens 1988). Of course, optimization of operating room productivity begins with identification of the proper case-mix to treat.

The study variables are the top 50 surgical DRGs performed in the NMCP catchment area, an aggregate total composed of both direct care surgeries and procedures performed in civilian facilities through CHAMPUS. Direct care refers to treatment at MTFs (NMCP in this GMP). Surgical DRGs are those discharges (coded) with at least one operating room procedure (Fetter and Freeman 1986).

Data was derived from the Central Retrospective Case-Mix Analysis System for an Open System Environment (RCMAS-OSE), a management information system developed by the Defense Medical Systems Support Center for the Resource Analysis and Management Systems of the Office of the Assistant Secretary of Defense - Health Affairs (OASD-HA), Health Services Operations Branch. In RCMAS-OSE, DRGs are used as case-mix measurement units and are an operational means of defining and measuring case-mix by grouping patients who are similar clinically and in terms of resource consumption (U. S. Department of Defense 1993). Additionally, RCMAS-OSE allows users to select DRGs as criteria when generating ad hoc reports.

METHODS AND PROCEDURES

Butler (1995) recommends using an existing linear programming model tailored to individual needs. The template used in this GMP is the Hughes and Soliman model. This model is clear, practical and replicable and historical data pertaining to NMCP is available to formulate model equations.

The decision to focus on the top fifty DRGs is based on historical utilization patterns. According to data from the FY 1994 Hospital Core Workload report, NMCP had 8,936 surgical discharges in FY 1994 (Naval Medical Center Portsmouth 1994). This number approaches the total number of surgical discharges for the entire NMCP catchment area in FY 1994 (see table 6, column 5) for the top fifty surgical DRGs. The total number from table 6, appendix A, column 5 is 10,293 discharges. Therefore, the focus on the top 50 surgical DRGs approximates (even exceeds) the number of surgical discharges from FY 1994.

Linear programming models involve formulating two functions into mathematical terms (Austin and Beckerman 1995). The first function in this GMP is the maximization of CHAMPUS cost avoidance -- this is the objective function that expresses the DRGs to be maximized. The second function requires that constraints or linear inequalities be expressed as equations limiting the solution space of the objective function. Quantitative Systems for Business Plus (QSB +), Version 3 decision support software was used to solve the linear programming model (QSB + Ver. 3). This software uses the simplex

method to solve the problem. The simplex method is an iterative computational procedure that calculates the optimal solution (Levin et. al. 1992). This method is based on the theory of linear algebra and works by taking a sequence of square submatrices and solving for the variables in such as way that successive solutions always improve, until a point in the algorithm is reached where improvement is no longer possible (Gregory 1995). The constraints for this model are the availability of surgical bed days and available operating room time. These constraints are considered structural. Originally intensive care unit and post anesthesia recovery unit data were to be included in the study, but complete data was not available and these constraints were eliminated.

In linear programming, the objective function expresses the variables to be maximized or minimized as a linear function of a set of decision variables. In this GMP, the objective function is maximization of CHAMPUS cost avoidance. For each study DRG, an individual contribution margin (or in this case, CHAMPUS cost avoidance) was calculated. This is similar to the Hughes and Soliman model discussed in the literature review. However, this GMP focuses on cost-avoidance vice revenue maximization (Hughes and Soliman 1985). Figure 1, on the following page, outlines the process of estimating the CHAMPUS cost avoidance per surgical DRG.

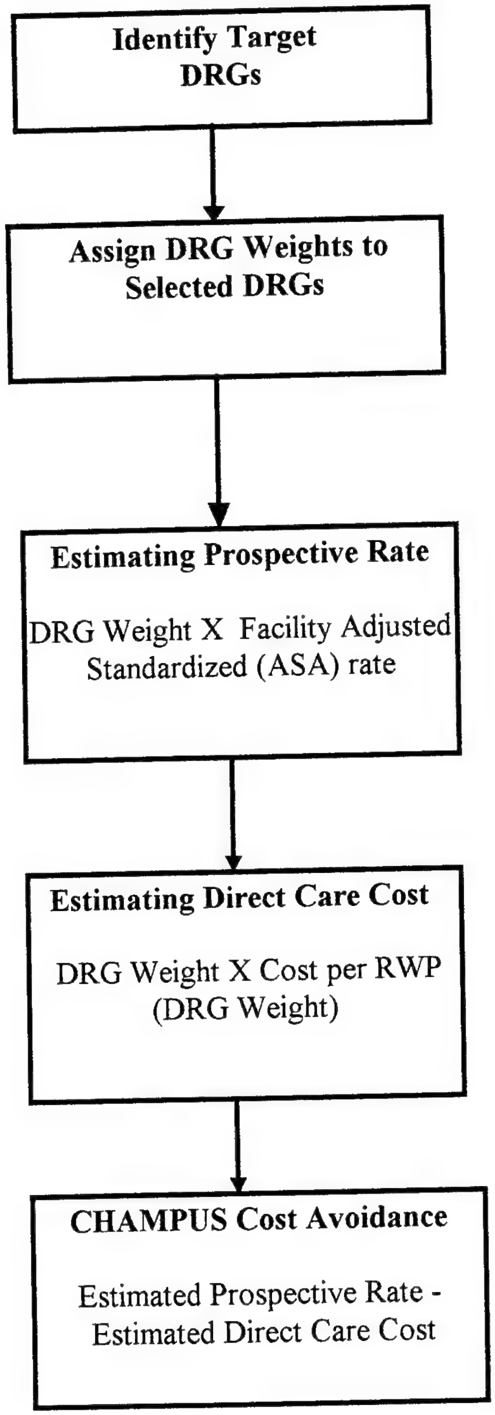

Fig. 1. Flowchart showing process to estimate CHAMPUS cost avoidance

Estimating the prospective rate (revenue) and cost per DRG both involve computing the Relative Weighted Product (RWP) earned by a case, which is a function of the DRG weight and the DRG Length of Stay (LOS) (Schaffer 1996). Each year, a DRG weight is assigned to each DRG by the Office of CHAMPUS (OCHAMPUS) and published in the Federal Register. Also published as this time is the arithmetic and geometric mean LOS. LOS is another weighing factor is assigning RWPs earned by a DRG case. In this GMP, all DRGs are considered inlier cases when calculating RWP credit earned, which simplifies deriving estimated revenues and costs per DRG (Schaffer 1996). As inlier cases, RWPs equal the given CHAMPUS DRG weight.

Therefore, we know the RWPs (or CHAMPUS DRG weight) for each DRG based on the weights listed yearly in the Federal Register. The next step is to translate each DRG into its prospective rate and an estimate of the direct care cost. This is done by using additional data: the Adjusted Standardized Amount (ASA) and an estimate of the average cost per RWP (Schaffer 1996).

As with DRG weights, ASAs are published yearly in the Federal Register. ASA's are published for each MTF and are based on the complexity of the hospital, such as level of teaching intensity present in the facility, the area's wage index and the Metropolitan Statistical Area (MSA) in which the facility is located. For FY 1995, NMCP's ASA rate was $5,268 (Schaffer 1996). To estimate the prospective DRG reimbursement, multiply the ASA rate ($5,268) by the number of RWPs earned by that case. For example, see table 6, column 6, in appendix A. This column lists the DRG weight for each surgical DRG. DRG 371 (Cesarean Section w/o CC) has a listed DRG weight of .7773 -- therefore .7773

* $5,268 = $4,094.82. This process is used to estimate all prospective payments listed in table 6.

A similar process is used to calculate total estimated cost. In military medicine, the cost allocation system used to estimate the cost per DRG is based on data from the Medical Expense & Performance Reporting System (MEPRS). Because this is not a patient-level accounting system, costs are aggregated at a high level and only average costs can be obtained (Schaffer 1996). However, the OASD-HA has developed a rudimentary methodology to cost out DRGs using the MEPRS (Schaffer 1996). This methodology computes the average dollar cost per RWP for a facility (NMCP in this GMP) and then uses this average cost amount to multiply by the RWPs of a particular DRG to estimate the DRG's cost. In FY 1994, NMCP's inpatient expenses (MEPRS "A" accounts) totaled $103,615,429.00 with a total of 21,915 RWPs completed at the hospital during the same year (Schaffer 1996). MEPRS "A" account refers to inpatient accounts and is a final operating account, incorporating indirect/overhead expenses (Schaffer 1996). Therefore, the average dollar cost per RWP is obtained by dividing these two totals -- $103,615,429/21,915 or approximately $4,728.06 per RWP. Thus for DRG 371, with a DRG weight of .7773, the cost estimate for NMCP is .7773*$4,728.06 = $3,675.12.

We now have the components necessary to estimate the CHAMPUS cost avoidance or contribution margin of each DRG: the DRG prospective payment amount minus the estimated direct care cost as defined above. Consequently, the contribution margin for DRG 371 is $4,094.82 - $3,675.12 = $419.70. See table 6, appendix A, column 9 for the estimated CHAMPUS cost avoidance for each study DRG.

It is important to note that while the absolute validity of these numbers is inconsequential, the relative values are very important. As long as the values are relative estimates of costs, the model will select the optimal mix of the decision variables.

Table 1. - - Objective function - maximization of CHAMPUS avoidance

CHAMPUS Avoidance DRG_1 + CHAMPUS Avoidance DRG_2 +. . . CHAMPUS Avoidance DRG_{50}

Source: See table 6, column 9.

The next step is identification of constraints. Constraints, expressed as linear equations or inequalities, specify the conditions or limitations which circumscribe the situation to be optimized (Dowling 1978). The DRGs used as variables in this model reflect surgical discharges from both NMCP and CHAMPUS in FY 1994 and are used to derive minimum and maximum numbers of discharges for each DRG. For the purpose of this model, no minimum number of DRGs is prescribed. A maximum number, derived from the total number of patient discharges in each DRG, is set for each diagnostic category and reflects the total number of patients treated in that category for the study year (FY 1994). The maximum number constrains the model from "selecting" more than the total number of patients in each DRG treated in the catchment area/direct care system during the study year (Dowling 1978). The use of upper bounds also prevents an unrealistic solution to the linear programming model in which the total number of patients treated in a few DRGs exceed the number actually available to NMCP (Dowling 1978).

Each capacity constraint represents an estimate of the maximum quantity of service that can be produced in a given year. Together these constraints form the hospital's pro-

duction-possibility frontier - which is the maximum attainable output of any one case type (DRG) for every possible combination of the others (Dowling 1978).

The first constraining resource is patient bed days. The average length of stay for each model DRG is available from the RCMAS-OSE data base. The data used for this model includes LOS outliers and uses the direct care (NMCP) LOS historical data from Fiscal Year (FY) 1994, not the CHAMPUS LOS. This was done to better approximate DRG LOS applicable to NMCP. For FY 1994, the number of patient bed days for surgical patients was 21,455 (Naval Medical Center Portsmouth 1994). Table 6, appendix A, column 10 lists the ALOS per DRG. Therefore the first constraint is:

Table 2. - - Constraining resource - patient bed days

ALOS DRG_1 + ALOS DRG_2 + . . . ALOS DRG_{50} $\leq$ 21, 455 Days

Source: RCMAS - OSE and the Hospital Core Workload Report FY 1994, Progress Reports and Statistics Department, Director for Resources, NMCP, Virginia.

Computation of surgical capability total is based on the total elective capacity, non-differentiated by elective and non-elective procedures. The surgical capacity is based on the use of 14 operating rooms, open 3 days a week and 15 operating rooms open 2 days a week (Naval Medical Center Portsmouth 1995b). For the purpose of this study, all operating rooms are considered operational 8 hours a day, 52 weeks a year. Therefore, the calculations are:

14 Operating Rooms * 3 Days/Week * 8 Hours/Day * 52 Weeks/Year = 17,472 hours

15 Operating Rooms * 2 Days/Week * 8 Hours/Day * 52 Weeks/Year = 12,480 hours

This gives a combined total of 29,952 available hours a year. However, even the most efficient teaching hospitals have utilization rates for operating room suites averaging around 65% (Clemens 1988). For this GMP, the total is adjusted down to 50% (to 14,976 hours) to ensure a more realistic linear programming model and to compensate for factors not included in this model (i.e. turnover time between operations, need for emergency surgery) and to adjust to the limitations present in this study. See table 6, appendix A, column 11, for estimates of each average surgery time per DRG (Naval Medical Center Portsmouth 1995b).

Table 3. - - Constraining resource - surgical capacity

Average Surgical Time DRG_1 + Average Surgical Time DRG_2 +. . . Average Surgical Time $DRG_{50} \leq$ 14, 976 hours

Source: NMCP Surgical Directorate Memorandum to the author, NMCP, Virginia, December 1995.

Even the behavior of relatively simply physical systems is fundamentally unpredictable (Freedman 1992). Therefore, in a complex system such as NMCP, it is absolutely essential to focus on the dynamics of the overall system (Freedman 1992). Accordingly, several limitations are built into the linear programming model. First, although same-day surgery is identified as an inpatient stay for rate-setting purposes, all study variables are considered inpatient surgical procedures (Munuz et al. 1994). All study DRGs have avercage LOS over 1 day. Also, study variable constraint data for surgical time and yearly capacity was generated by direct provider figures and are an approximation of average times and maximum capacity. Because these are subjective estimates of relative use, they may

be biased, since physicians were not systematically surveyed (Dowling 1978). Additionally, surgical procedures are non-differentiated among operating room capacity -- that is, operating rooms for this model are considered homogenous and interchangeable. Obstetrical procedures are also included in the model as if they are performed in the main operating room suites, average times for obstetrical procedures was provided by the Labor and Delivery Ward (Newell 1996).

THE RESULTS

The solution to the linear program is located on page 29, Appendix B. The maximum value of CHAMPUS avoidance (given this model) is $4,667,524.00. Given the CHAMPUS avoidance calculated for each DRG and the corresponding utilization of both surgical and bed capacity, NMCP should avoid treating patients in DRGs 60, 261, 63, 53, 158, 163, 224 or 468 (see table 4). According to this model, resources would be better served by focusing on the other DRGs in the model, and perhaps surgical DRGs not included in the model.

Table 4. - - Non-optimal surgical DRGS

DRG 60	Tonsillectomy &/or Adenoidectomy Only, Age 0 - 17
DRG 261	Breast Proc for Nonmalignancy Except Biopsy & Local Excision
DRG 63	Other Ear, Nose, Mouth & Throat Procedures
DRG 53	Sinus & Mastoid Procedures Age > 17
DRG 158	Anal & Stomal Procedures w/o CC
DRG 163	Hernia Procedures 0 - 17
DRG 224	Shoulder, Elbow or Forearm Proc, Exc Major Joint Proc, w/o CC
DRG 468	Extensive OR Procedure Unrelated to Principal Diagnosis

Source: QSB 3.0 + Output

Intuitively, by comparing pertinent data for commensurate DRGs, one can readily see how the linear programming model selects variables. DRG 225 (Foot Procedures) has an estimated CHAMPUS avoidance amount of $474.34, a corresponding average LOS of 1.44 days and surgical consumption (operating room) time averaging 2.00 hours, while DRG 158 (Anal & Stomal Procedures w/o CC) has an estimated CHAMPUS avoidance amount of $299.67, a corresponding average LOS of 1.42 days and surgical consumption time averaging 3.50 hours. As you can see, DRG 158 provides much less return and higher resource consumption than DRG 225 and is not an optimal target for the study.

If the hospital does decide to treat patients in these other DRGs, the opportunity cost column in appendix B lists the amounts the total contribution margin would be reduced by treating a patient in that DRG. For example, if NMCP decided to provide treatment to a patient in DRG 468 (Extensive OR Procedure Unrelated to Principle Diagnosis), the total CHAMPUS avoidance maximum will be reduced by $293.87 per case.

Table 5 is the constraint summary for the linear solution. The surplus value of zero for both constraining resources means that (in this model) NMCP is making full use of both constraining resources. If the surplus value had a positive number this would indicate excess capacity for the associated resource (bed days or surgical hours). The shadow price is the value by which NMCP could increase total CHAMPUS cost avoidance by adding a unit of the constraining resource. For every additional hour of surgical capacity available, the potential gain in avoiding CHAMPUS expenditures is approximately $160.45.

Table 5. - - Slack variables and shadow prices

Constraint	Constraint Status	Shadow Price	Surplus	Minimum R. H. S.	Current R. H. S.	Maximum R. H. S.
Bed Days	Tight (≤)	00.00	00.00	-M	21455	M
Surgical Hours	Tight (≤)	160.4524	00.00	-M	14976	M

Source: QSB 3.0 + Output

Most of the limitations of the linear programming model are directly related to problems in gathering data. Another limitation is that this study is significantly simplified in that it focuses only on a very small segment of hospital production. Additionally, the results of the model, in regard to the optimal mix of surgical DRGs, ignore political and global concerns central to patient care at NMCP, including continuance of Graduate Medical Education programs.

Another problem results from inherent systems problems. Much of the data simply was not readily available, for example, the average time for surgical procedures (arrayed by surgical DRGs) was not readily available; a problem certainly not unique to NMCP, and referenced in the literature (Calmes and Shusterich 1992). Dowling relates a similar problem in his 1978 study:

> departmental capacities depend on a number of factors which were too complex to be fully handled in this study. The development of more exact estimates would require more accurate measures of departmental inputs and outputs and a more complete understanding of the production functions of the medical departments, or the specifications of authoritative productivity standards (Dowling 1978).

The literature recommends several steps to improve the availability of data. These steps include "identification of sequential work activities (SWAs) that are critical to the timely progression of surgical cases through the operating room, identification of a time standard for completion of SWAs, direct observations of the amount of time required for completion of SWAs, and analysis of the results" (Weimer 1993). The forthcoming installation of the computerized scheduling system for the operating rooms at NMCP should simplify and standardize data collection efforts.

Finally, this simple model addresses only one stage in the surgical production process nothing is said about the manner in which other primary human and physical inputs are combined to produce services (Dowling 1978). This model also does not address the appropriateness of the amounts or types of services provided to the different categories of patients (Dowling 1978).

DISCUSSION

Completion of this GMP and the steps involved in gathering data and completing the design of the model reflect concerns present in the literature regarding the use of operations research techniques such as linear programming. One common criticism is that linear programming results amount to "(quick) results that are unencumbered with sophistication" (Phillips, Simmons and Simmons 1991).

Other problems stem from the need to develop the practical value of operations research methods and the need to identify policies and actions beyond project funding and technical assistance that will sustain the process of organizational research, change, and development that the process is designed to achieve (Phillips, Simmons and Simmons 1991).

One solution suggested in the literature is to "institutionalize" the process of using techniques such as linear programming. According to one source, institutionalization of operations research is said to exist if it is an established activity with indigenous technical, organizational, and financial resources, and if the research provides credible information (Phillips, Simmons and Simmons 1991) that offers managers the capacity to analyze, predict, and control the behavior of the complex organizations they lead (Freedman 1992). Another important factor is use of multidisciplinary teams to facilitate planning decisions that use techniques such as linear programming, rather than dividing problems up along disciplinary lines that defeat the purpose of having teams (Burton et. al 1978). Addition-

ally, with multidisciplinary teams, the specialized knowledge is available to make intelligent decisions.

Nonetheless, as our health care system reaches critical mass as financial and quality pressures continue to mount, the inevitability of increased reliance on the techniques of operations research is unavoidable. Therefore, increased pressures will fall on health care managers to critically apprise the merits of said techniques, particularly since many fail to discuss behavioral and managerial aspects of implementation (Butler 1995).

Moreover, serious questions need to be asked before implementation of other operations research studies. These questions include: 1) which problems are amenable to research; 2) which problems are capable of being solved through administrative action; 3) is potential problem relevant; and 4) is a potential problem salient (Fisher and Miller 1991)? In regard to that last question, Fisher and Miller suggest that "if a potential solution to a problem cannot be implemented in a larger area or throughout a system, an operations research study of such a problem will have little impact" (Fisher and Miller 1991). Another factor affecting use of operations research results is dissemination of the results (Martin et al. 1991).

The impact of the results also depends on strong understanding and support from top management and the clinical staff - who can choose to adopt solutions which, if supported by sound reasoning and adequate justification, do not conform to the established way of doing things (Singh, May and Messick 1978). Of course, this is a very difficult process and "conformity and bureaucratic routine have positive psychological value and suggesting change can provoke anxiety" (Singh, May and Messick 1978).

CONCLUSION AND RECOMMENDATIONS

For many civilian, for-profit hospitals, strategic planning is tantamount to building a business strategy. These hospitals track key indicators of business success such as the cost and estimate of revenues of the DRGs in this GMP (Beckham 1995). However, non-profit hospitals and their boards often are not interested in business strategy and tend to react to political and community pressures, as opposed to making radical, proactive decisions. At NMCP, executive decision makers must realize that the mission of NMCP - providing patient care, education and research - is a costly endeavor, with many of the costs passed on to taxpayers (Clemens 1988).

Because of the size and nature of NMCP, the hospital is in a unique position to capitalize on its leverage with other providers of health care services in the Hampton Roads area. One possible business strategy suggested in the literature is a focus on advanced acute-care capability (Beckham 1995). A focus that would require analysis of DRGs similar to the results presented in this GMP. Accordingly, a plausible scenario for the future of military health care in the Hampton Roads area is NMCP/ACF as a

> highly specialized hospital that is focused *only* (italics mine) on those capabilities that can be performed in an acute inpatient setting. This advanced hospital would build high volume in its uniquely sophisticated areas of clinical concentration and would engage in a constant recycling of technologies so that it is always the repository for the very latest advances (Beckham 1995).

Interestingly enough, in the same Beckham article reference above, Sentara - the Norfolk, Virginia based health system - who is already a provider of managed care style primary care for MHSS beneficiaries, is quoted as no longer interested in running hospitals but, instead, is focusing on primary care, enrolled lives, and reduced operating costs (Beckham 1995).

Results of this study indicate that NMCP can not be "all things to all people." Perhaps an increased focus on those procedures that NMCP provides cost-effectively coupled with further aggressive analysis of true costs and demand for services will help military health administrators devise a truly seamless and efficient health care system that truly maximizes use of all resource dollars.

Specifically, the linear model formulated in this GMP, could be modified to support decision making along a wide spectrum of facility resource matters. An ideal situation would involve a mult-disciplinary committee, including health care providers and fiscal experts designing a more complex linear model. Another application of this technique could aid regional cooperation between service health care facilities within Tricare (the term for the MHSS managed care plan) regions.

For example, imagine three Military Treatment Facilities (MTFs) in the same Tricare region. The first, an Army hospital approaching its capacity to provide certain services, while another Navy facility has excess capacity, and yet another MTF can accommodate all the specialized cardiac care required by MHSS beneficiaries in the entire region. A complex linear programming model could be used to indicate the number and

types of patients that could be shifted between hospitals to produce a higher overall level of efficiency (Dowling 1978).

Results of this GMP, and perhaps future refinement of the methodology, can lead to more knowledgeable and sophisticated analysis and systems modification leading to a more business-like philosophy with sound financial bottom lines (Clemens 1988). Perhaps the results of this GMP can increase the focus on economic and operations research methodologies and their applications to health systems problems which have not heretofore been touched (Singh, May and Messick 1978).

Appendix A

Table 6. - - DRG data matrix

DRG (1)	Nomenclature (2)	NMCP Direct Care Cases (3)	NMCP CHAMPUS Cases (4)	Total (5)	CHAMPUS DRG Weight (6)	Total Estimated Prospective Payment (7)	Total Estimated Cost (8)	CHAMPUS Avoidance (9)	ALOS (days) (10)	Average Surgical Time (hours) (11)
371	Cesarean Section w/o CC	227	631	858	0.7773	$4,094.82	$3,675.12	$419.70	3.41	1.15
359	Uterine & Adnexa Proc for Nonmalignancy w/o CC	275	240	515	0.9401	$4,952.45	$4,444 85	$507.60	3.08	2.33
215	Back & Neck Procedures w/o CC	316	90	406	1.2447	$6,557.08	$5,885.02	$672.06	2.76	2.50
62	Myringotomy w Tube Insertion Age 0-17	374	3	377	0.7197	$3,791.38	$3,402.78	$388.59	1.02	0.50
56	Rhinoplasty	375	2	377	0.9107	$4,797.57	$4,305.84	$491.72	1.07	1.50
222	Knee Procedures w/o CC	352	19	371	1.1066	$5,829.57	$5,232.07	$597.50	1.89	3.50
231	Local Excision & Removal of Int Fix Devices Except Hip & Femur	363	7	370	1.095	$5,768.46	$5,177.23	$591.23	1.56	0.83
370	Cesarean Section with CC	163	175	338	0.9822	$5,174.23	$4,643.90	$530.33	4.4	2.00
374	Vaginal Delivery w Sterilization &/or D&C	43	293	336	0.6673	$3,515.34	$3,155.03	$360.30	2.5	0.33
162	Inguinal & Femoral Hernia Procedures Age > 17 w/o CC	333	2	335	0.6539	$3,444.75	$3,091.68	$353.07	1.18	1.50
361	Laparoscopy & Incisional Tubal Interruption	283	2	285	0.8436	$4,444.08	$3,988.59	$455.49	1.29	1.50
262	Breast Biopsy & Local Excision for Nonmalignancy	279	0	279	0.8641	$4,552.08	$4,085.52	$466.56	1.01	0.83
39	Lens Procedures w or w/o Vitrectomy	243	0	243	0.5868	$3,091.26	$2,774.43	$316.84	1.08	1.00
362	Endoscopic Tubal Interruption	241	1	242	0.5189	$2,733.57	$2,453.39	$280.17	1.02	1.00
229	Hand or Wrist Proc,Except Major Joint Proc, w/o CC	239	1	240	0.7047	$3,712.36	$3,331.86	$380.50	1.3	2.00
270	Other Skin, Subcut Tissue, & Breast Procedure w/o CC	235	4	239	0.7089	$3,734.49	$3,351.72	$382.76	1.26	1.50
288	O.R. Procedures for Obesity	82	135	217	1.634	$8,607.91	$7,725.65	$882.26	1.15	2.00
494	Laparoscopic cholecystectomy	206	7	213	1.0318	$5,435.52	$4,878.41	$557.11	2.29	1.83
225	Foot Procedures	197	13	210	0.8785	$4,627.94	$4,153.60	$474.34	1.44	2.00
55	Miscellaneous Ear, Nose, Mouth, & Throat Procedures	195	13	208	0.829	$4,367.17	$3,919.56	$447.61	1.18	2.00
60	Tonsillectomy &/or Adenoidectomy Only, Age 0-17	184	4	188	0.4283	$2,256.28	$2,025.03	$231.26	1.03	1.60
261	Breast Proc for Nonmalignancy Except Biopsy & Local Excision	103	79	182	1.0218	$5,382.84	$4,831.13	$551.71	1.25	3.50
167	Appendectomy w/o Complicated Principal Diag w/o CC	170	9	179	0.7227	$3,807.18	$3,416.97	$390.21	2.14	1.83
381	Abortion w D&C, Aspiration Curettage, or Hysterectomy	168	10	178	0.4782	$2,519.16	$2,260.96	$258.20	1.08	0.50
63	Other Ear, Nose, Mouth & Throat O.R. Procedures	155	15	170	1.2481	$6,574.99	$5,901.09	$673.90	2.62	4.20
53	Sinus & Mastoid Procedures Age > 17	155	2	157	0.8784	$4,627.41	$4,153.13	$474.28	1.35	3.50
59	Tonsillectomy &/or Adenoidectomy Only, Age > 17	145	0	145	0.5237	$2,758.85	$2,476.09	$282.77	1.04	1.00
268	Skin, Subcutaneous Tissue & Breast Plastic Procedures	132	7	139	0.9216	$4,854.99	$4,357.38	$497.61	1.34	1.00
339	Testes Procedures, Nonmalignancy Age > 17	135	0	135	1.1413	$6,012.37	$5,396.13	$616.23	1.21	1.50
358	Uterine & Adenexa Proc for Nonmalignancy w CC	88	44	132	1.1689	$6,157.77	$5,526.63	$631.14	4.94	1.82
158	Anal & Stomal Procedures w/o CC	126	4	130	0.555	$2,923.74	$2,624.07	$299.67	1.42	3.50
477	Non-extensive OR Procedures Unrelated to Principal Diagnosis	114	13	127	1.35	$7,111.80	$6,382.88	$728.92	1.67	0.25
40	Extraocular Procedures Except Orbit Age > 17	126	0	126	0.8167	$4,302.38	$3,861.41	$440.97	1.03	1.63
342	Circumcision Age > 17	120	0	120	0.6689	$3,523.77	$3,162.60	$361.17	1	1.22
160	Hernia Procedures Except Inguinal & Femoral Age > 17 w/o CC	109	8	117	0.6502	$3,425.25	$3,074.18	$351.07	1.54	1.50
219	Lower Extrem & Humer Proc Except Hip, Foot, Femur Age > 17 w/o CC	103	13	116	1.0662	$5,616.74	$5,041.06	$575.68	3.39	3.00
112	Percutaneous Cardiovascular Procedures	33	76	109	2.2615	$11,913.58	$10,692.51	$1,221.07	4.48	5.00
163	Hernia Procedures 0 -17	106	1	107	0.4992	$2,629.79	$2,360.25	$269.54	1.03	2.00
6	Carpal Tunnel Release	106	0	106	0.6339	$3,339.39	$2,997.12	$342.27	1.04	1.50
214	Back and Neck Procedures w CC	69	36	105	2.1444	$11,296.70	$10,138.85	$1,157.85	3.6	3.00
227	Soft Tissue Procedures w/o CC	92	13	105	0.8085	$4,259.18	$3,822.64	$436.54	1.91	1.00
224	Shoulder, Elbow or Forearm Proc, Exc Major Joint Proc, w/o CC	93	5	98	0.8096	$4,264.97	$3,827.84	$437.14	1.68	3.83
267	Perianal & Pilonidal Procedures	90	0	90	0.5056	$2,663.50	$2,390.51	$272.99	1.02	0.75
311	Transurethral Procedures w/o CC	80	5	85	0.7208	$3,797.17	$3,407.99	$389.19	1.45	1.75
468	Extensive OR Procedure Unrelated to Principal Diagnosis	58	26	84	2.4274	$12,787.54	$11,476.89	$1,310.65	3.77	10.00
148	Major Small & Large Bowel Procedures w CC	67	16	83	3.2431	$17,084.65	$15,333.57	$1,751.08	9.97	4.25
266	Skin Graft &/or Debrid for Skin Ulcer or Cellulitis w/o CC	73	9	82	1.0412	$5,485.04	$4,922.86	$562.19	3.11	1.33
75	Major Chest Procedures	69	11	80	3.1426	$16,555.22	$14,858.40	$1,696.82	11.48	4.00
364	D&C, Conization,Except for Malignancy	78	2	80	0.6161	$3,245.61	$2,912.96	$332.66	1.49	1.00
232	Arthroscopy	79	0	79	0.9407	$4,955.61	$4,447.69	$507.92	1.04	2.00

Sources: (3), (10) U. S. Department of Defense 1993, FY 1994 (Including Outliers) Direct Care, RCMAS-OSE output
(4) U. S. Department of Defense 1993, FY 1994 (Including Outliers) CHAMPUS, RCMAS-OSE output
(6) (CHAMPUS Weights and Threshold Summary 1994, 51947-51957)
(7) ASA Rate ($5268) * CHAMPUS DRG Weight
(8) Average Dollar Cost Per RWP ($4728.06) * CHAMPUS DRG Weight
(11) Naval Medical Center Portsmouth 1995b

Table 7. - - Linear Programming Solution

Variable Number	Variable Name	Solution	Opportunity Cost	Minimum Obj. Coef.	Current Obj. Coef.	Maximum Obj. Coef.
1	DRG 371	858	235.1798	- M	419.7	-184.5202
2	DRG 359	515	133.7459	- M	507.6	-373.8541
3	DRG 215	406	270.929	- M	672.06	-401.131
4	DRG 062	377	308.3638	- M	388.59	-80.2262
5	DRG 056	377	251.0414	- M	491.72	-240.6786
6	DRG 222	371	36	- M	597.5	-561.5834
7	DRG 231	370	458.0545	- M	591.23	-133.1755
8	DRG 370	338	209.4252	- M	530.33	-320.9048
9	DRG 374	336	307.3507	- M	360.3	-52.94929
10	DRG 162	335	112.3914	- M	353.07	-240.6786
11	DRG 361	285	214.9114	- M	455.59	-240.6786
12	DRG 262	279	333.3845	- M	466.56	-133.1755
13	DRG 039	243	156.3876	- M	316.84	-160.4524
14	DRG 362	242	119.7176	- M	280.17	-160.4524
15	DRG 229	240	59.59521	- M	380.5	-320.9048
16	DRG 270	239	142.0814	- M	382.76	-240.6786
17	DRG 288	217	561.3552	- M	882.26	-320.9048
18	DRG 494	213	263.4821	- M	557.11	-293.6279
19	DRG 225	210	153.4352	- M	474.34	-320.9048
20	DRG 055	208	126.7052	- M	447.61	-320.9048
21	DRG 060	0	25.46384	- M	231.26	256.7238
22	DRG 261	0	9.873357	- M	551.71	561.5834
23	DRG 167	179	96.5821	- M	390.21	-293.6279
24	DRG 381	178	177.9738	- M	258.2	-80.2262
25	DRG 063	0	0	- M	673.9	M
26	DRG 053	0	87.30338	- M	474.28	561.5834
27	DRG 059	145	122.3176	- M	282.77	-160.4524
28	DRG 268	139	337.1576	- M	497.61	-160.4524
29	DRG 339	135	375.5514	- M	616.23	-240.6786
30	DRG 358	132	339.1166	- M	631.14	-292.0234
31	DRG 158	0	261.9134	- M	299.67	561.5834
32	DRG 477	127	688.8069	- M	728.92	-40.1131
33	DRG 040	126	179.4326	- M	440.97	-261.5374
34	DRG 342	120	165.4181	- M	361.17	-195.7519
35	DRG 160	117	110.3914	- M	351.07	-240.6786
36	DRG 219	116	94.32281	- M	575.68	-481.3572
37	DRG 112	109	418.808	- M	1221.07	-802.262
38	DRG 163	0	51.36478	- M	269.54	320.9048
39	DRG 006	106	101.5914	- M	342.27	-240.6786
40	DRG 214	105	676.4928	- M	1157.85	-481.3572
41	DRG 227	105	276.0876	- M	436.54	-160.4524
42	DRG 224	0	177.3926	- M	437.14	614.5327
43	DRG 267	90	152.6507	- M	272.99	-120.3393
44	DRG 311	85	108.3983	- M	389.19	-280.7917
45	DRG 468	0	293.8739	- M	1310.65	1604.524
46	DRG 148	83	1069.157	- M	1751.08	-681.997
47	DRG 266	82	348.7883	- M	562.19	-213.4017
48	DRG 075	80	1055.01	- M	1696.82	-641.8096
49	DRG 364	80	172.2076	- M	332.66	-160.4524
50	DRG 232	79	187.0152	- M	507.92	-320.9048

Maximized Objective = $4,667,524.00

Source: QSB + 3

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